Indicator: Visibility (006)

Visibility impairment is one of the most obvious effects of air pollution. It is observed not only in urban areas, but also in many of the best known and most treasured natural parks and wilderness areas, such as the Grand Canyon, Great Smoky Mountains, Mount Rainier, Shenandoah, Yellowstone, and Yosemite National Parks. (Latest Findings on National Air Quality–2002 Status and Trends, EPA 454/K-03-001). Visibility impairment occurs when air pollution, both particles and gases, scatter and absorb light. This not only limits the distance one can see, but can also degrade the color, clarity, and contrast of scenes. As the Indicator "Ambient PM Concentrations" describes further, the same pollutants that impair visibility are also linked to serious health effects.

The particles that impair visibility include both primary and secondary pollutants. The primary pollutants of concern are particles that sources emit directly into the atmosphere, like dust from roads or soot (elemental carbon) from wood combustion. The secondary pollutants, on the other hand, are particles that form in the atmosphere from chemical reactions and physical processes involving sulfates (formed from sulfur dioxide emissions from power plants and other industrial facilities) and nitrates (formed from nitrogen oxides emitted from power plants, automobiles, and other types of combustion sources). Humidity can significantly increase the effect of pollution on visibility, causing some particles to become more efficient at scattering light and impairing visibility. (Latest Findings on National Air Quality–2002 Status and Trends, EPA 454/K-03-001)

In the eastern United States, where annual average relative humidity levels are between 70 and 80%, reduced visibility mainly results from secondarily formed sulfates and high humidity, along with a somewhat lower contribution from organic carbon and nitrates (EPA 2003). The effect of humidity is particularly strong in summer. In the western United States, on the other hand, primary emissions from sources like wood smoke and nitrates contribute a larger percentage of the total particulate loading, though secondarily formed sulfates also contribute to visibility impairment. Humidity is less of a factor in the West, as average values are generally between 50 and 60%. Without the effects of pollution, a natural visual range in the United States should be approximately 75 to 150 km (45 to 90 miles) in the East and 200 to 300 km (120 to 180 miles) in the West (Latest Findings on National Air Quality–2002 Status and Trends, EPA 454/K-03-001).

This indicator reports visibility data that were collected at 47 monitoring sites between 1992 and 2001 at National Parks and other protected sites under the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. The IMPROVE network began monitoring of 20 sites in 1988 and has since expanded to a network of 110 sites. Visibility is calculated from particle speciation data using an algorithm that estimates light extinction as the sum of each component mass concentration times its typical extinction efficiencies. The algorithm includes an adjustment for ammonium sulfate and ammonium nitrate to account for their adsorption of water vapor from the atmosphere under elevated relative humidity conditions. The IMPROVE particle data is generated by laboratory analysis of 24-hour duration filter samples collected at each site on a one day in three schedule. The worst and best visibility conditions presented here refer to the mean of the 20% worst visibility days and mean of the best 20% visibility days at each site each year.

What the Data Show

Visibility data are presented separately for the Eastern (Figure 006-1) and the Western (Figure 006-2) United States. Each figure shows how the average visibility (in kilometers) changed from one year to the next for days with best visibility, mid-range visibility, and worst visibility.

The figures show that the worst visibility in the West is comparable to the best visibility in the East. In 2001, the mean visual range for the worst days in the East was 29 km (18.1 miles), compared to 117 km (73.1 miles) for the best visibility days. In the West, the mean visual range ranged from 103 km (64 miles) on the worst days to 234 km (145 miles) on the best days. In both regions, visibility trends remained fairly stable between 1992 and 2001.

Indicator Limitations

- These data represent visibility in a sampling of selected national park and wilderness areas and are not representative of other rural or urban areas.

Data Sources

Interagency Monitoring of Protected Visual Environments (IMPROVE) network - http://vista.cira.colostate.edu/improve/

References

U.S. Environmental Protection Agency. Latest Findings on National Air Quality–2002 Status and Trends, EPA 454/K-03-001. Research Triangle Park, NC; U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, August 2003.

U.S. Environmental Protection Agency. The Particulate Pollution Report: Current Understanding of Air Quality and Emissions through 2003, EPA 454/R-04-002. Research Triangle Park, NC; U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, December 2004.

U.S. Environmental Protection Agency. The Ozone Report: Measuring Progress through 2003, EPA 454/K-04-001. Research Triangle Park, NC; U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, April 2004.

Graphics

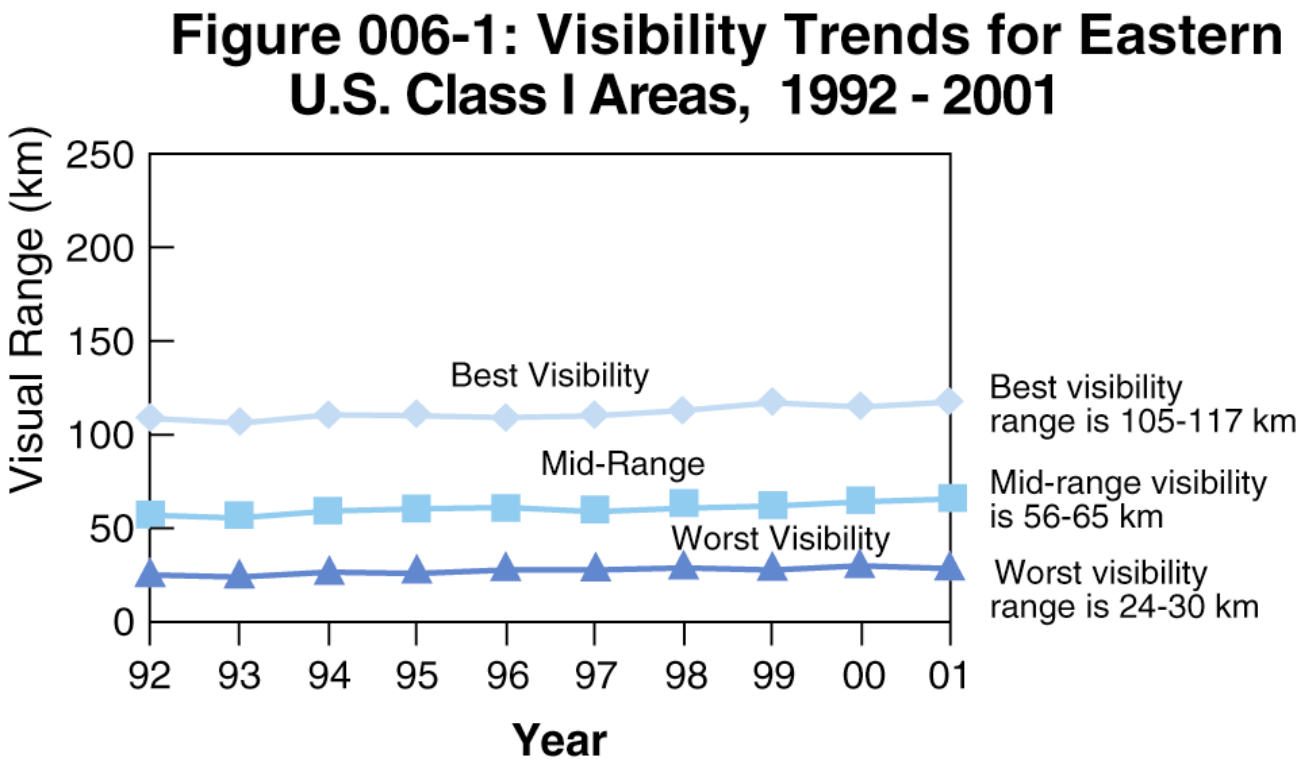
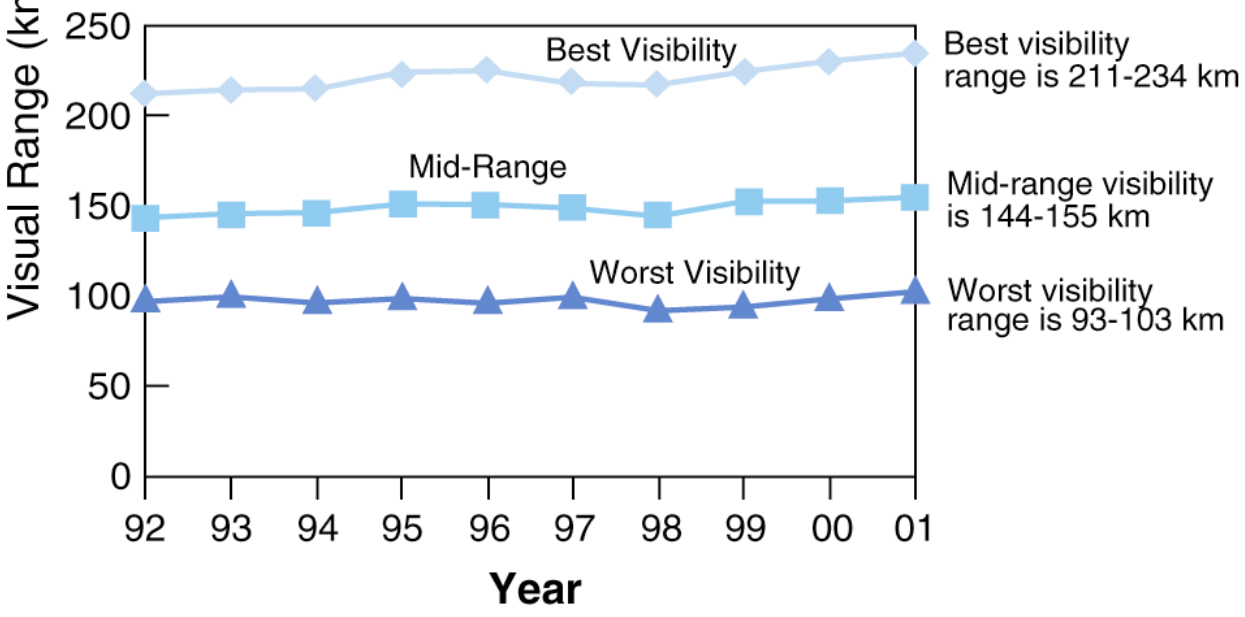


Figure 006-1: Visibility Trends for Eastern U.S. Class I Areas, 1992 - 2001
Visual Range (km)
250
200
150
100
50
0
92
93
94
95
96
97
98
99
00
01
Year
Best Visibility
Mid-Range
Worst Visibility
Best visibility range is 105-117 km
Mid-range visibility is 56-65 km
Worst visibility range is 24-30 km

Figure 006-2: Visibility Trends for Western U.S. Class I, Areas, 1992 - 2001



R.O.E. Indicator QA/QC

Data Set Name: VISIBILITY
Indicator Number: 006 (89071)
Data Set Source: IMPROVE Monitoring Network database at: http://vista.cira.colostate.edu/improve/
Data Collection Date: 1992-2001
Data Collection Frequency: Wednesdays & Saturdays throughout the year
Data Set Description: Trends in Visibility
Primary ROE Question: What are the trends in outdoor air quality and effects on human health and ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. The Interagency Monitoring of Protected Visual Environments (IMPROVE) was established as a cooperative effort among EPA, states, National Park Service, U.S. Forest Service, Bureau of Land Management, and U.S. Fish and Wildlife Service. The IMPROVE data guide provides a detailed overview of the IMPROVE samplers and analysis. This document can be downloaded at the following web site - http://vista.cira.colostate.edu/improve/Publications/otherDocs/IMPROVEDataGuide/IMPROVEDataGuide.htm IMPROVE has also been a key participant in visibility-related research, including the advancement of monitoring instrumentation, analysis techniques, visibility modeling, policy formulation and source attribution field studies.

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. The IMPROVE monitoring program was established in 1985 to aid the creation of Federal and State implementation plans for the protection of visibility in Class I areas (156 national parks and wilderness areas) as stipulated in the 1977 amendments to the Clean Air Act. In 2000, the IMPROVE Monitoring Network started an expansion from 30 to 110 monitoring sites. The expansion work was completed in the fall of 2001. States, tribes, and federal land management agencies support more than 50 additional sites. Collectively, these will be used to track future progress in accordance with the regional haze program. The network samplers monitor on Wednesdays and Saturdays throughout the year, yielding 104 samples per year and 26 samples per season. To be included in this analysis, sites were required to have data for at least 50 percent of the scheduled samples (13 days) for every calendar quarter. IMPROVE monitoring sites are selected as trends sites if they have complete data for at least 8 of the 10 years between 1990 and 1999 (or 6 of 8 years for those who began monitoring in 1992).

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Yes. The source data sets were obtained from Dr. James Sisler of Colorado State University. The annual average statistics in these files were used to assess trends. The IMPROVE data are not reported in terms of a calendar year. The IMPROVE year runs from March to February of the following year. It follows that the four seasons are: March to May (spring), June to August (summer), September to November (autumn), and December to the following February (winter). The network samplers monitor on Wednesdays and Saturdays throughout the year, yielding 104

samples per year and 26 samples per season. To be included in this analysis, sites were required to have data for at least 50 percent of the scheduled samples (13 days) for every calendar quarter. IMPROVE monitoring sites are selected as trends sites if they have complete data for at least 8 of the 10 years between 1990 and 1999 (or 6 of 8 years for those who began monitoring in 1992). A year is valid only if there are at least 13 samples (50 percent complete) per season for both measured and reconstructed PM2.5. The same linear interpolation applied to the criteria pollutants is applied here. The IMPROVE sites meeting the data completeness criteria are shown in Figure B-1 (National Air Quality and Emissions Trends Report, 2003). For consistency, the same sites are used in both the PM2.5 section. The exceptions are Washington, DC, and South Lake Tahoe, which are not included in the visibility trends analysis because they are urban sites.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

Recognizing the importance of visual air quality, congress included legislation in the 1977 Clean Air Act to prevent future and remedy existing visibility impairment in Class I areas. To aid the implementation of this legislation, the IMPROVE program was initiated in 1985. This program implemented an extensive long term monitoring program to establish the current visibility conditions, track changes in visibility and determine causal mechanism for the visibility impairment in the National Parks and Wilderness Areas.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

The IMPROVE sites meeting the data completeness criteria are shown in Figure B-1 (National Air Quality and Emissions Trends Report, 2003). For consistency, the same sites are used in both the PM2.5 section. The exceptions are Washington, DC, and South Lake Tahoe, which are not included in the visibility trends analysis because they are urban sites.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

There are no established national standards, but background visibility ranges from approximately 7 deciviews (182-193 km) in the western U.S. to 11-14 deciviews (100-130 km) in the eastern U.S. Malm, W.C. 1999. Introduction to Visibility. Cooperative Institute for Research in the Atmosphere (CIRA), NPS Visibility Program, Colorado State University, Fort Collins, CO 80523. http://www.epa.gov/air/visibility/introvis.pdf

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Detailed information about the improve monitoring sites including location, sampling equipment and history of changes at the monitoring site can be found at http://vista.cira.colostate.edu/improve/Web/MetadataBrowser/MetadataBrowser.aspx?State=CO&Program=IMPROVE&MeasurementType=Aerosol

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

Yes. The aerosol and optical data are made publicly available approximately nine months after collection. In addition, seasonal and annual data reports, special study data reports, technical publications, and other data and analysis reports are prepared. These IMPROVE resources can be

obtained from this website - http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. The description of the IMPROVE network can be found http://vista.cira.colostate.edu/improve/

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

The IMPROVE Quality Management Plan (QMP) for the environmental data operations of the Aerosol Monitoring Network component of the IMPROVE Visibility Monitoring Program outlines the roles of organizations involved in the IMPROVE Aerosol Monitoring Network. The IMPROVE Aerosol Quality Assurance Project Plan developed by Crocker Nuclear Laboratory documents the quality assurance and quality control activities of the IMPROVE Aerosol monitoring network. These documents can be downloaded at the following web site - http://vista.cira.colostate.edu/improve/Publications/publications.htm

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Yes. The annual average statistics in these files were used to assess trends. The IMPROVE data are not reported in terms of a calendar year. The IMPROVE year runs from March to February of the following year. It follows that the four seasons are: March to May (spring), June to August (summer), September to November (autumn), and December to the following February (winter). The network samplers monitor on Wednesdays and Saturdays throughout the year, yielding 104 samples per year and 26 samples per season. To be included in this analysis, sites were required to have data for at least 50 percent of the scheduled samples (13 days) for every calendar quarter. IMPROVE monitoring sites are selected as trends sites if they have complete data for at least 8 of the 10 years between 1990 and 1999 (or 6 of 8 years for those who began monitoring in 1992). A year is valid only if there are at least 13 samples (50 percent complete) per season for both measured and reconstructed PM2.5. The same linear interpolation applied to the criteria pollutants is applied here. The IMPROVE sites meeting the data completeness criteria are shown in Figure B-1 (National Air Quality and Emissions Trends Report, 2003). For consistency, the same sites are used in both the PM2.5 section. The exceptions are Washington, DC, and South Lake Tahoe, which are not included in the visibility trends analysis because they are urban sites.

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

In addition, the IMPROVE data undergo extensive QA/QC procedures and analyses by its contractors and the National Park Service before it is released. UC Davis conducts three levels of QA/QC on the aerosol sampling equipment and data. For a full description see the Data Processing and Validation SOP. A copy of these procedures can be downloaded from http://vista.cira.colostate.edu/improve/Publications/SOPs/UCDavis_SOPs/sop351.pdf

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

This web site - http://vista.cira.colostate.edu/improve/Data/QA_QC/issues.htm documents issues and potential problems with the IMPROVE data and its interpretation. When possible, recommendations are provided for minimizing the influence of these issues on data analysis.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

Limitations of this indicator include the following: " The indicator compares trends within visibility range categories, but it would also be useful to indicate how often visibility falls into each range during a year. " The data represent only a sampling of national park and wilderness areas; nevertheless, this indicator provides a good picture of the impact of air pollution on the nation s parks and protected areas. As of 2001, the network monitored 110 sites.